Optical Glass

[0001]

Background of the Invention

1. **Field of the Invention**

The present invention relates to an optical glass that has a medium to high refractive index and high dispersion characteristics, can be pressed at relative low temperature, and has a relatively low sag temperature and liquidus temperature.

[0002]

2. **Description of Related Art**

A number of glasses having medium to high refractive indexes and high dispersion characteristics are known.

For example, Japanese Patent Un-examined Publication No. Hei 07-97234 describes a low melting point optical glass having a medium to high refractive index and high dispersion characteristics and comprising prescribed quantities of P_2O_5, Na_2O, Nb_2O_5, and WO_3. This optical glass is described as having a refractive index of 1.69-1.83, a dispersion ratio of 21-32, and a sag temperature of not more than 570°C. However, when comparison is conducted between the examples described in Japanese Patent Un-examined Publication No. Hei 07-97234 having a refractive index of not greater than 1.73, those glasses characterized by having a sag temperature Ts exceeding 520°C are numerous. This is attributed to an Li_2O content of 0-0.5 weight percent. Further, there are also examples (Examples 6, 7, and 8) in which Ts is less than 520°C even with an Li_2O content within the range of 0-0.5 weight percent. In that case, there is the problem of the use of expensive GeO_2 as a glass starting material. When the GeO_2 is removed from the glasses of these examples, the liquidus temperature (also referred to hereinafter as "LT") ends up exceeding 900°C. This is attributed to a P_2O_5 content of not greater than 32 percent.

[0003]

Japanese Patent Un-examined Publication No. Hei 05-270853 describes an

optical glass having a medium to high refractive index and high dispersion characteristics and comprising prescribed quantities of SiO_2, B_2O_3, P_2O_5, Nb_2O_5, and Na_2O + K_2O. In the glasses described in this publication, all the glasses described in the examples having a refractive index of 1.64-1.73 have liquidus temperatures exceeding 900°C. This is attributed to a P_2O_5 content of not greater than 32 weight percent. Further, these glasses also have a Ts exceeding 520°C. This is attributed to an Na_2O content of not greater than 5 weight percent.

[0004]

Japanese Patent Un-examined Publication No. Shō 52-132012 describes an optical glass having a medium to high refractive index and high dispersion characteristics and comprising prescribed quantities of B_2O_3, P_2O_5, and Nb_2O_5. The glasses described in the examples of this publication, which have refractive indexes of 1.64-1.73, all have a Ts exceeding 520°C. This is attributed to an Na_2O content not exceeding 5 weight percent. Excluding the glasses described in Examples 2 and 3, the lack of Li_2O is thought to result in a Ts exceeding 520°C. Even in the glasses of Examples 2 and 3 which comprise Li_2O in a quantity exceeding 0.5 weight percent, the Ts exceeds 520°C and the liquidus temperature exceeds 900°C. This is attributed to a P_2O_5 content of not more than 32 weight percent and an Nb_2O_5 content exceeding 30 weight percent.

[0005]

The press-molding of glass is normally conducted within a high temperature range exceeding the sag temperature temperature Ts of the glass by about 20-60°C. When the yield temperature of the glass exceeds 520°C, the press temperature becomes at least 540°C. Thus, the glass has a strong tendency to react with the molding surface of the mold, shortening the service life of the mold and rendering the glass unsuited to mass production.

When the liquidus temperature is high, the glass tends to lose transparency in the vicinity of its softening point, that is, in the vicinity of the molding temperature in press-molding.

[0006]

Further, the glass preforms employed in reheating presses are required not to have variation in shape and weight. Thus, when forming preforms by shaping molten glass, the shaping is conducted at a prescribed viscosity where there tends not to be variation in shape and weight. Thus, when the glass is at a temperature at which the viscosity is suited to shaping, it must not tend to lose transparency, that is, the liquidus temperature must be lower than the temperature at which viscosity is suited to shaping. From these perspectives, the liquidus temperature is required to be 800-900°C.

[0007]

However, in the above-described glasses, almost all of those glasses having a refractive index falling within a range of 1.64-1.72 and an Abbé number of 29-36 have a sag temperature temperature exceeding 520°C and a liquidus temperature exceeding 900°C. In glasses used in press-molding, when the life of the mold and the tendency of the glass to lose transparency are considered, a sag temperature of not greater than 520°C and a relatively low liquidus temperature, particularly one not greater than 900°C, are desirable.

[0008]

Accordingly, the object of the present invention is to provide an optical glass having a medium to high refractive index and high dispersion characteristics, the liquidus temperature of which is comparatively low, specifically not greater than 900°C, and more particularly, an optical glass the refractive index of which falls within the range of 1.64-1.72 and the Abbé number of which falls within the range of 29-36.

[0009]

[Summary of the Invention]

The invention relates to an optical glass comprising, by means of weight percentages, more than 32 percent and not more than 45 percent P_2O_5, more than 0.5 percent and not more than 6 percent Li_2O, more than 5 percent and not more than 22 percent Na_2O, 6-30 percent Nb_2O_5, 0.5-10 percent B_2O_3, 0-35 percent WO_3, 0-14 percent K_2O, and 10-24 percent $Na_2O + K_2O$, and the total of all the above

components is not less than 80 percent.

With the above optical glass, the glass preferably comprises, by means of weight percentages, more than 32 percent and not more than 40 percent P_2O_5, 1-4 percent Li_2O, 10-19 percent Na_2O, 10-28 percent Nb_2O_5, 1-5 percent B_2O_3, 0-8 percent K_2O, and 12-22 percent $Na_2O + K_2O$, and the total of all the above components is not less than 80 percent. With this optical glass, the glass more preferably comprises 12-17 percent Na_2O, 15-26 percent Nb_2O_5, 0-4 percent K_2O, and 14-19 percent $Na_2O + K_2O$.

With the above optical glasses, the glass may further comprise, by means of weight percentages, 0-2 percent SiO_2, 0-5 percent Al_2O_3, not less than 0 percent but less than 8 percent TiO_2, 0-15 percent ZnO, 0-12 percent BaO, 0-18 percent WO_3, not less than 0 percent but less than 1 percent Sb_2O_3, and 0-1 percent SnO_2, and the total of all of the above components and the components listed in any one of claims 1 to 3 is not less than 95 percent. With this optical glass, the glass preferably comprises, by means of weight percentages, 0-3 percent Al_2O_3, 0-6 percent TiO_2, and 0-9 percent ZnO, where the total of all of the components listed is not less than 95 weight percent; and the glass preferably comprises 0-1 percent SiO_2.

With the above optical glasses, the glass may comprise not less than 0 percent but less than 0.5 percent SiO_2, 0-5 percent TiO_2, 0-5 percent ZnO, and the total of all of the components listed is not less than 98 percent; and the glass may further comprise 3-15 weight percent WO_3.

The invention further relates to an optical glass comprised phosphate glass which comprises, by means of weight percentages, more than 0.5 percent and but not more than 6 percent Li_2O, more than 5 percent but not more than 22 percent Na_2O, 0-14 percent K_2O, 10-24 percent $Na_2O + K_2O$, 6-30 percent Nb_2O_5, and not more than 45 percent P_2O_5, and exhibits a refractive index (nd) of 1.64-1.72, an Abbé number (vd) of 29-36, and a sag temperature (Ts) of not greater than 520°C; and an optical glass comprised of phosphate glass which comprises, by means of weight percentages, more than 0.5 percent but not more than 6 percent Li_2O, more than 5 percent but not more than 22 percent Na_2O, 0-14 percent K_2O, 10-24 percent $Na_2O + K_2O$, 6-30

percent Nb_2O_5, 0-35 percent WO_3, 0-5 percent Al_2O_3, and not less than 0 percent but less than 8 percent TiO_2, and exhibits a refractive index (nd) of 1.64-1.72, an Abbé number (vd) of 29-36, and an sag temperature (Ts) of not greater than 520°C.

With these glasses, the glass preferably comprises more than 32 weight percent but not more than 45 weight percent P_2O_5.

The invention still further relates to an optical glass comprising, by means of weight percentages, more than 32 percent but not more than 45 percent P_2O_5, more than 0.5 percent but not more than 6 percent Li_2O, more than 5 percent but not more than 22 percent Na_2O, 6-30 percent Nb_2O_5, 0.5-10 percent B_2O_3, 0-35 percent WO_3, 0-14 percent K_2O, 10-24 percent $Na_2O + K_2O$, 0-2 percent SiO_2, 0-5 percent Al_2O_3, not less than 0 percent but less than 8 percent TiO_2, 0-15 percent ZnO, 0-12 percent BaO, not less than 0 percent but less than 1 percent Sb_2O_3, and 0-1 percent SnO_2, where the total of the contents of each of the above-listed components is not less than 95 percent, the refractive index (nd) is 1.64-1.72, the Abbé number (vd) is 29-36, and the sag temperature (Ts) is not more than 520°C.

The invention further relates to an optical glass comprised of phosphate glass which comprises Li_2O, Na_2O, Nb_2O_5, and B_2O_3 as essential components, and not more than 2 weight percent SiO_2 an optional component, with a refractive index (nd) of 1.64-1.72, an Abbé number (vd) of 29-36, a sag temperature (Ts) of not more than 520°C, and a liquidus temperature (LT) of not more than 900°C.

With this optical glass, the glass may further comprise, by means of weight percentages, more than 32 percent but not more than 45 percent P_2O_5, more than 0.5 percent but not more than 6 percent Li_2O, more than 5 percent but not more than 22 percent Na_2O, 6-30 percent Nb_2O_5, and 0.5-10 percent B_2O_3.

With all of the optical glasses mentioned above, the glass may further comprises, by means of weight percentages, 0-5 percent MgO, 0-5 percent CaO, 0-5 percent SrO, 0-3 percent La_2O_3, 0-3 percent Y_2O_3, 0-3 percent Gd_2O_3, 0-3 percent ZrO_2, not less than 0 percent but less than 1 percent As_2O_3, 0-3 percent Ta_2O_5, 0-3 percent In_2O_3, 0-3 percent TeO_2, 0-3 percent Bi_2O_3, and 0-1 percent GeO_2, where the total of the above-listed components and the components described in any one of

claims 1 to 14 is not less than 99 percent.

The invention still further relates to an optical article comprised of the optical glass according to the present invention; an optical glass for precision press-molding wherein the glass is one according to the present invention; a glass preform obtained by preforming the above optical glass; a glass optical article obtained by reheat press-molding the above glass preform; and an optical article obtained by press-molding the optical glass according to the present invention.

Brief Description of the Drawings

Fig. 1 is a cross-sectional view of a schematic of an example of a precision press-molding device.

[0010]

Detailed Description of the Invention

Below, unless expressly stated otherwise, nd denotes the refractive index, νd denotes the Abbé number, Ts denotes the yield temperature, and LT denotes the liquidus temperature.

The glass of the present invention differs from the glass described in Japanese Patent Un-examined Publication No. Hei 07-97234 not only by essentially not comprising or comprising not more than 1 percent expensive GeO_2 as a glass starting material, but also by having a Ts of not more than 520°C and in that the pressing temperature can be lowered. Further, the glass of the present invention has a liquidus temperature of not greater than 900°C, permitting the molding with heat of a preform in the stage prior to press-molding without causing striae, the adhesion of volatile matter, or improper shape.

Further, the glass of the present invention differs from the glass described in Japanese Patent Un-examined Publication No. Hei 05-270853 in that the liquidus temperature is reduced to not more than 900°C by incorporating a quantity of P_2O_5 exceeding 32 percent. Thus, the molding with heat of a preform in the stage prior to press-molding can be conducted without causing striae, the adhesion of volatile matter, or improper shape. Further, since the glass of the present invention

incorporates more than 5 weight percent Na_2O, the Ts is lower than 520°C, so it is not necessary to raise the pressing temperature of the press machine, affording the advantage of not applying a heat load to the press machine.

Further, the glass of the present invention differs from the glass described in Japanese Patent Un-examined Publication No. Shō 52-132012 by comprising more than 5 weight percent Na_2O, more than 0.5 weight percent Li_2O, more than 32 weight percent P_2O_5, and not more than 30 weight percent of Nb_2O_5, yielding a glass for precision press with a Ts of not greater than 520°C and a liquidus temperature of not greater than 900°C.

[0011]

In the present Specification, the word "percent" refers to a percentage by weight unless specifically stated otherwise.

Further, oxides are denoted by their representative chemical symbols and include the case where the oxide reduction states of Ti, Nb, W, Sb, Sn, Zr, As, Ta, In, Te, Ge, and the like have been modified. Specifically, the case where Ti is partially reduced to obtain $TiO_{1.9}$ is also covered and denoted as TiO_2.

The reasons for limiting each of the components of the glass of the present invention, and more particularly, the glasses described in claims 1-8, will be described below.

P_2O_5 is a glass forming component. In the glass of the present invention, to achieve a sag temperature of not greater than 520°C and good resistance to loss of transparency, phosphate glass is desirable, phosphate glass comprising not more than 45 weight percent P_2O_5 is preferred, and phosphate glass comprising not less than 32 weight percent and not more than 45 weight percent P_2O_5 is even more preferred. When the content of P_2O_5 exceeds 45 weight percent, the targeted refractive index (1.64 or greater) becomes difficult to achieve. Considering nd>1.66 and chemical durability, the P_2O_5 content desirably exceeds 32 weight percent but does not exceed 40 weight percent.

[0012]

Li_2O is a component having the effect of reducing the Ts. When the Li_2O

content is not greater than 0.5 weight percent, it is impossible to achieve the targeted characteristic of Ts≤520°C. When the Li_2O content exceeds 6 weight percent, it becomes impossible to achieve the targeted characteristic of a liquidus temperature of not greater than 900°C. When the content of Li_2O is kept within the range of 1-4 weight percent, a glass in which Ts≤510°C and the liquidus temperature≤860°C can be achieved, which is desirable for manufacturing.

[0013]

Na_2O is a component having the effect of lowering the Ts. When the Na_2O content is not greater than 5 weight percent, it becomes impossible to achieve the targeted characteristic of Ts≤520°C. When the Na_2O content exceeds 22 weight percent, chemical durability deteriorates. An Na_2O content within the range of 10-19 weight percent is desirable in that chemical durability is good and a glass in which Ts≤510°C and the liquidus temperature is not greater than 860° can be achieved. An Na_2O content within the range of 12-17 weight percent is preferred in that chemical durability is good and a glass in which Ts≤510°C and the liquidus temperature is not greater than 840°C can be achieved.

[0014]

Nb_2O_5 is a component imparting to glass the characteristics of nd≥1.64 and νd≤36. When the Nb_2O_5 content is less than 6 weight percent, the targeted refractive index (nd≥1.64) and the dispersion characteristic (νd≤36) cannot be achieved. When the Nb_2O_5 content exceeds 30 weight percent, the liquidus temperature ends up exceeding 900°C. The Nb_2O_5 content is preferably 10-28 weight percent. Within this range, nd≥1.66, the liquid phase transition temperature≤860°C, and Ts≤510°C. The Nb_2O_5 content is more preferably within the range of 15-26 weight percent. Within this range, a glass in which nd≥1.66 and the liquid phase transition temperature≤840°C can be achieved.

[0015]

B_2O_3 is a component that complements the glass forming component P_2O_5 and lowers the liquidus temperature. When the B_2O_3 content is less than 0.5 weight percent, the liquidus temperature ends up exceeding 900°C. When the B_2O_3 content

exceeds 10 weight percent, the Ts ends up exceeding 520°C. The B_2O_3 content is desirably 1-5 weight percent. Within this range, a glass in which Ts≤510°C and the liquid phase transition temperature≤860°C can be achieved.

[0016]

WO_3 is an optional component. When added in a suitable quantity of not greater than 35 weight percent, it is possible to readily adjust nd within the range of 1.64-1.72 and vd within the range of 36-29 while maintaining the characteristics of Ts≤520°C and the liquidus temperature (denoted as "LT" hereinafter) ≤900°C. When the WO_3 content exceeds 35 weight percent, coloration intensifies. The WO_3 content desirably falls within the range of 0-18 weight percent. Within this range, coloration tends not to occur and it is possible to readily adjust nd within the range of 1.65-1.71 and vd within the range of 35.5-30 while maintaining the characteristics of Ts≤510°C and LT≤860°C. The WO_3 content preferably falls within the range of 3-15 weight percent. Within this range, it is possible to readily adjust nd within the range of 1.66-1.70 and vd within the range of 35-30 while maintaining the characteristics of Ts≤510°C and LT≤840°C.

[0017]

K_2O is an optional component. When added in a suitable quantity of not greater than 14 weight percent, it is possible to readily adjust nd within the range of 1.64-1.72 and vd within the range of 36-29 while maintaining the characteristics of Ts≤520°C and LT≤900°C. When the K_2O content exceeds 14 weight percent, chemical durability deteriorates. The K_2O content desirably falls within the range of 0-8 weight percent. Within this range, chemical durability tends not to deteriorate and it is possible to readily adjust nd within the range of 1.65-1.71 and vd within the range of 35.5-30 while maintaining the characteristics of Ts≤510°C and LT≤860°C. The K_2O content preferably falls within the range of 0-4 weight percent. Within this range, it is possible to readily adjust nd within the range of 1.66-1.70 and vd within the range of 35-30 while maintaining the characteristics of Ts≤510°C and LT≤840°C.

[0018]

$Na_2O + K_2O$ is a component that has the effect of lowering the Ts. When the $Na_2O + K_2O$ content is less than 10 weight percent, it becomes impossible to achieve the targeted characteristic of Ts≤520°C. When the $Na_2O + K_2O$ content exceeds 24 weight percent, chemical durability deteriorates. When the $Na_2O + K_2O$ content falls within the range of 12-22 weight percent, chemical durability is good and a glass in which Ts≤510°C and the liquidus temperature is not greater than 860°C is achieved. Particularly, when the $Na_2O + K_2O$ content falls within the range of 14-19 weight percent, chemical durability is good and a glass is achieved in which Ts≤510°C and the liquidus temperature is not greater than 840°C.

[0019]

SiO_2 is an optional component. When added in a suitable quantity of not greater than 2 weight percent, it is possible to readily adjust nd within the range of 1.65-1.71 and vd within the range of 35.5-30. When the SiO_2 content exceeds 2 weight percent, Ts sometimes exceeds 520°C. Further, in consideration of glass coloration, when melting is made with a SiO_2 crucible, a quantity of from 0 weight percent to less than 0.5 weight percent SiO_2 may mix into the glass. Thus, the quantity of SiO_2 is desirably set to from 0 weight percent to less than 0.5 weight percent. In the optical glass described in claim 7, the content of SiO_2 is desirably from 0 weight percent to not greater than 0.4 weight percent.

[0020]

Al_2O_3 is an optional component. When added in a suitable quantity of not greater than 5 weight percent, the chemical durability of the glass improves. However, when added in a quantity exceeding 5 weight percent, the melting properties of the glass when melting the glass starting material deteriorate and the melting temperature increases. As a result, when conducting melting in a Pt crucible, the quantity of Pt mixed in increases and problems such as coloration tend to result. When melting is conducted in an Si crucible, the amount of Si mixing in increases and Ts exceeds 520°C. The Al_2O_3 content desirably falls within the range of 0-3 weight percent.

[0021]

TiO_2 is an optional component. When added in a suitable quantity of less than 8 weight percent, the chemical durability of the glass improves, nd rises, and vd permits high dispersion. However, when TiO_2 is added in a quantity of 8 percent or greater, coloration tends to develop. The TiO_2 content is preferably 0-6 weight percent, more preferably falling within the range of 0-5 weight percent. In the optical glass described in claim 7, the TiO_2 content is preferably 0-4.9 weight percent.

[0022]

ZnO is an optional component. When added in a suitable quantity of not greater than 15 weight percent, the chemical durability of the glass increases and Ts is lowered. However, when added in a quantity exceeding 15 weight percent, vd sometimes exceeds 36. The preferred ZnO content is 0-9 weight percent, with 0-5 weight percent being more preferred.

[0023]

BaO is an optional component. When added in a suitable quantity of not greater than 12 weight percent, nd can be readily adjusted within the range of 1.65-1.71 and vd within the range of 35.5-30. However, the addition of a quantity exceeding 12 weight percent is undesirable because LT exceeds 900°C. The preferred BaO content is 0-6 weight percent.

[0024]

Sb_2O_3 and As_2O_3 are optional components. Addition in suitable quantity has the effects of debubbling and clarifying. It also has the effect of inhibiting reduction coloration of Nb_2O_5, TiO_2, WO_3, and the like. However, when Sb_2O_3 is added in a quantity of one weight percent or above, the Sb_2O_3 itself develops strong coloration. Thus, the suitable range for the addition of Sb_2O_3 is from 0 to less than 1 weight percent. Further, when As_2O_3 is added in a quantity of 1 weight percent or greater, the As_2O_3 itself develops strong coloration. Thus, the suitable range for the addition of As_2O_3 is from 0 to less than 1 weight percent.

[0025]

SnO_2 is an optional component. Addition in a suitable quantity of less than 1 weight percent has the effects of debubbling and clarifying. It also has the effect

of inhibiting reduction coloration of Nb_2O_5, TiO_2, WO_3, and the like. However, when SnO_2 is added in a quantity of one weight percent or above, the SnO_2 itself develops strong coloration. Thus, the suitable range for the addition of SnO_2 is from 0 to less than 1 weight percent.

[0026]

MgO, CaO, and SrO are optional components. Their addition in suitable quantities facilitates the adjustment of nd within the range of 1.65-1.71 and vd within the range of 35.5-30. However, their respective addition in quantities exceeding 5 weight percent is undesirable in that LT exceeds 900°C. The respective contents of MgO, CaO, and SrO are desirably 0-3 weight percent.

[0027]

La_2O_3, Y_2O_3, Gd_2O_3, ZrO_2, Ta_2O_5, In_2O_3, TeO_2, and Bi_2O_3 are optional components the addition of each of which in suitable quantity facilitates the adjustment of nd within the range of 1.65-1.71 and vd within the range of 35.5-30. However, their respective addition in quantities exceeding 3 weight percent is undesirable in that LT exceeds 900°C. The respective content of each of these components is desirably 0-1 weight percent.

[0028]

The optical glass of the present invention desirably does not comprise PbO in view of safety. Further, because of the high cost of GeO_2, it is desirably either not incorporated or incorporated within a range of 0-1 weight percent.

[0029]

In the glass described in claims 1 and 2, the total of the components described in each of the claims is not less than 80 percent. This is desirable to achieve the characteristics of a liquidus temperature of not greater than 900°C and a sag temperature of 520°C in a refractive index range of 1.64-1.72 and an Abbé number range of 29-36.

Further, in the glass described in claims 4 and 5, the total of components described in each of the claims is not less than 95 percent. This is desirable to provide a glass with a liquidus temperature of not greater than 900°C and a sag

temperature of not greater than 520°C in a refractive index range of 1.64-1.72 and an Abbé number range of 29-36, as well as a glass having no practical problems with chemical durability and coloration.

[0030]

Further, the liquidus temperature (LT) of the optical glass of the present invention is normally not greater than 900°C. The quantities of the various components added are desirably adjusted to yield an LT of not greater than 860°C, and more preferably, not greater than 840°C. The sag temperature (Ts) is normally not greater than 520°C. The quantities of the various components added are desirably adjusted to yield a Ts of not greater than 510°C.

[0031]

The reasons for limiting the content of the various components in the form of Li_2O, Na_2O, K_2O, Na_2O + K_2O, and Nb_2O_5 of the phosphate glass described in claim 9 are identical to those of above-described claims 1-8. The reason for incorporating not more than 45 percent P_2O_5 is identical to that for the glass of claims 1-8. In the phosphate glass described in claim 9, the refractive index is 1.64-1.72, the Abbé number is 29-36, and the sag temperature is not greater than 520°C. Glass having a medium to high refractive index and high dispersion characteristics with the above-stated refractive index and Abbé number is suited to use in optics. From the viewpoint of glass used in press-molding, the sag temperature is not greater than 520°C in consideration of the service life of the mold and the tendency of the glass to lose transparency. Optical glass having such a refractive index, Abbé number, and sag temperature can be suitably obtained from glass comprising the various components described in claim 9 within the ranges stated in claim 9. It is also desirable to incorporate 0.5-10 weight percent B_2O_3 and 0-4.9 weight percent TiO_2 into the glass described in claim 9.

[0032]

The reasons for limiting the content of the various components in the form of Li_2O, Na_2O, K_2O, Na_2O + K_2O, Nb_2O_5, WO_3, Al_2O_3, and TiO_2 of the phosphate glass described in claim 10 are identical to those of above-described claims 1-8. Further,

the refractive index is 1.64-1.72, the Abbé number is 29-36, and the sag temperature is not greater than 520°C. Glass having a medium to high refractive index and high dispersion characteristics with the above-stated refractive index and Abbé number is suited to use in optics. From the viewpoint of glass used in press-molding, the sag temperature is not greater than 520°C in consideration of the service life of the mold and the tendency of the glass to lose transparency. Optical glass having such a refractive index, Abbé number, and sag temperature can be suitably obtained from glass comprising the various components described in claim 10 within the ranges stated in claim 10.

[0033]

In the glasses described in claims 9 and 10, the P_2O_5 content desirably exceeds 32 percent but does not exceed 45 percent (claim 11). The reason for this is the same as for limiting the content of P_2O_5 in the invention described in claim 1.

[0034]

The reasons for limiting the content of the various components in the form of P_2O_5, Li_2O, Na_2O, Nb_2O_5, B_2O_3, WO_3, K_2O, $Na_2O + K_2O$, SiO_2, Al_2O_3, TiO_2, ZnO, BaO, WO_3, Sb_2O_3, and SnO_2 of the glass described in claim 12 are identical to those of above-described claims 1-8. Further, the refractive index is 1.64-1.72, the Abbé number is 29-36, and the sag temperature is not greater than 520°C. Glass having a medium to high refractive index and high dispersion characteristics with the above-stated refractive index and Abbé number is suited to use in optics. From the viewpoint of glass used in press-molding, the sag temperature is not greater than 520°C in consideration of the service life of the mold and the tendency of the glass to lose transparency. Optical glass having such a refractive index, Abbé number, and sag temperature can be suitably obtained from glass comprising the various components described in claim 12 within the ranges stated in claim 12. The total quantity of the above-listed components is not less than 95 percent. This is desirable to achieve characteristics of a liquidus temperature of not greater than 900°C and a sag temperature of not greater than 520°C within a refractive index range of 1.64-1.72 and an Abbé number range of 29-36.

[0035]

The reasons for limiting the various components in the glass described in claims 13-18 is identical to the reason for limiting the various components in the optical glass described in claims 1-8.

In the glass described in claims 15-18, the total of the components described in each of the claims is not less than 99 percent. This is desirable to achieve characteristics of a liquidus temperature of not greater than 900°C and a sag temperature of not greater than 520°C within a refractive index range of 1.64-1.72 and an Abbé number range of 29-36. In the optical glass described in claims 1-18, the total quantity of P_2O_5, Li_2O, Na_2O, Nb_2O_5, B_2O_3, WO_3, Al_2O_3, TiO_2, ZnO, and Sb_2O_3 is desirably not less than 95 weight percent, preferably not less than 99 weight percent, and more preferably, 100 weight percent.

[0036]

The optical glass of the present invention can be manufactured by mixing, melting, clarifying, stirring, and homogenizing the starting compounds by the usual methods.

The present invention can also provide materials for precision press-molding comprised of the optical glass of the present invention, optical articles comprised of the optical glass, and optical articles obtained by precision press-molding the materials for precision press-molding.

The material for precision press molded of the present invention is characterized by being comprised of the above-described optical glass of the present invention.

[0037]

Here, the term precision press-molding is used to mean press-molding in which an optically functioning surface is shaped by press-molding, and the term material for precision press-molding is used to mean a molded glass material used during precision press-molding.

As an example of precision press-molding, first, a glass melt having a viscosity of 0.1-5 dPa·s at 1,000-1,200°C that has been melted, stirred, clarified and

homogenized is flowed out of a flow pipe, received in a mold (generally different from the pressing mold), and a spherical, elliptical, or similarly shaped material for precision press molding called a preform is produced. The preform is then reheated and pressure molded by an upper and lower mold. In this process, in view of the shape of the molded article, a drum mold may be used in combination.

The preform may be formed by mechanically processing a cooled glass or shaping a molten glass, or may be further ground to a mirror surface.

[0038]

Methods of shaping a molten glass include dripping or flowing melted glass out of a flow pipe, receiving the melt in a receiving mold via a gas, and molding it to a desired shape such as a sphere or oblate sphere.

When the melt is dripped, a 0.1-5 dPa·s melt is adjusted to a viscosity permitting dripping, and the melt is dripped to obtain a spherical or elliptical preform. The glass that is dripped may be solidified while falling, or may be floated on a gas flow and solidified while being rotated.

When the melt is flowed, a 0.1-5 dPa·s melt is adjusted to a viscosity suited to flowing and made to flow out of a flow pipe. The glass flowed out is severed and received in a mold via a gas, and the glass is molded into a sphere or oblate sphere and solidified. The glass that is made to flow down is preferably severed without use of a cutting blade. For example, after glass that has been made to flow down by such a method has been received in the receiving mold, the receiving mold can be lowered to sever the glass.

[0039]

The viscosity of the glass that is made to drip or flow from a pipe in the course of molding by dripping or flowing glass into a preform is preferably not less than 5 dPa·s. Further, the viscosity of dripping glass is more preferably 3-30 dPa·s, and the viscosity of flowing glass is more preferably 5-60 dPa·s.

At that time, to increase the viscosity of the 0.1-5 dPa·s melt to higher than 5 dPa·s, the temperature within the pipe through which the melt flows is made 1,000-800°C, or more preferably, the temperature of the front end of the flow pipe is

decreased to 900-800°C. At that time, in conventional optical glass with a liquidus temperature exceeding 900°C, the viscosity is quite low when the temperature at the front end of the pipe exceeds 900°C and the glass does not mold, causing the preform to crystallize. Thus, even when the melt has been received in the mold, improper deformation and striae result.

[0040]

By contrast, the optical glass of the present invention has a low liquidus temperature of not greater than 900°C, and since a stable glass state is maintained even at a viscosity suited to preform molding, the preform does not crystallize even when heat molded by a method such as that set forth above and striae and improper deformation do not occur.

[0041]

[Isothermal Pressing]

Fig. 1 is a cross-sectional schematic view of an example of a precision press-molding device. In the device of Fig. 1, a mold comprising an upper mold 1, a lower mold 2, and a guide mold 3 is positioned on a support base 10 provided on a support rod 9. This assembly is positioned within a quartz tube 11 around which is coiled a heater 12. The molded glass preform 4 of the medium to high refractive index high dispersion optical glass of the present invention may be in the form of a sphere or elliptical sphere about 0.5-50 mm in diameter. The size of the spherical or elliptical preform is suitably determined in consideration of the size of the final article.

After positioning molded glass preform 4 between lower mold 2 and upper mold 1, power is supplied to heater 12 to heat the interior of quartz tube 11. The temperature within the mold is controlled by a thermocouple 14 inserted into lower mold 2. The heating temperature is set to a temperature at which molded glass preform 4 assumes a viscosity suited to precision pressing, for example, a viscosity of 10^7-10^8 dPa·s. Once a prescribed temperature is reached, pressure rod 13 is dropped, pressing upper mold 1 from above and pressing glass preform 4 to be

molded within the mold. The pressure in the press and time are suitably determined in consideration of the glass viscosity and the like. For example, the pressure may fall within a range of about 5-15 MPa and the time within a range of 10-300 seconds. After pressing, the glass is gradually cooled to the glass transition temperature, and then rapidly cooled to room temperature. The molded article is then removed from the mold, yielding the optical article of the present invention.

[0042]

[Anisothermal Pressing]

The optical glass of the present invention can be applied to press-molding methods in which press-molding is conducted with a glass preform and a mold under temperature conditions such as the following

The glass preform is heated to a temperature corresponding to a viscosity in the glass preform of less than 10^9 dPa·s and softened. Because the viscosity of the glass preform is less than 10^9 dPa·s, it is possible to mold the glass material by substantially deforming it with a mold preheated to a temperature corresponding to a viscosity higher than 10^9 dPa·s. To conduct molding at a comparatively low temperature in the mold, the glass material is softened by heating to a temperature corresponding to $10^{5.5}$-$10^{7.6}$ dPa·s. The preheating temperature of the mold is a temperature corresponding to a viscosity of 10^9-10^{12} dPa·s in the glass material. At less than the temperature corresponding to a viscosity of 10^{12} dPa·s, it is sometimes difficult to greatly extend the glass material and obtain a glass molded article with a thin peripheral thickness. By contrast, at a temperature corresponding to a viscosity of 10^9 dPa·s, the molding cycle time becomes excessively long and the service life of the mold is shortened.

[0043]

[Direct Pressing]

It is also possible to conduct direct pressing from melted glass gobs. Since the liquidus temperature is low, at not greater than 900°C, this method affords the advantage of permitting a wide range in the selection of the temperature conditions at which the melt is made to flow from the flow pipe and pressing temperature

conditions without causing the glass to crystallize.

[0044]

[Common Press-molding]

Further, the optical glass of the present invention is also suited to press-molding methods employing grinding and polishing without just precision press-molding. The following are specific examples.

When manufacturing optical articles directly from melted glass that has been stirred and homogenized, the melted glass that has been stirred and homogenized is fed through a flow pipe to the upper surface of the lower mold of the press mold and the glass is pressure molded by the lower mold and an upper mold opposing the lower mold (called direct pressing). The molded article obtained can be ground and polished as needed to obtain an optical article.

Further, the homogenized melted glass can be temporarily cooled, processed the cooled glass into a desired shape, reheated, and pressure molded by the mold. The molded article obtained in this case can then also be ground and polished as needed to obtain an optical article.

Still further, optical articles can be manufactured by grinding and polishing.

[0045]

In each of the above-described molding methods, the shape of the upper mold, lower mold, and as needed, drum mold can be suitably selected to mold optical articles such as various lenses such as spherical lenses, aspherical lenses, microlenses, lens arrays, microlens arrays; prisms; and polygonal mirrors.

[0046]

[Examples]

The present invention is described in detail below through examples. However, the present invention is in no way limited to these examples.

The physical properties of the optical glass were measured by the following methods.

(1) Refractive index (nd) and Abbé number (vd)

Measured for optical glass obtained at a gradual cooling temperature drop

rate of -30°C/h.

(2) Sag temperature temperature (Ts)

Measurements were made with a thermal expansion measuring device at a temperature increase rate of 8°C/min.

(3) Liquidus temperature (LT)

The glass was maintained for 30 min in a transparency loss test furnace with a 400-1050°C temperature gradient and the presence or absence of crystals was observed by microscopy at a magnification of 100X to determine the liquidus temperature. Loss of transparency properties near the softening point (pressing temperature) was also observed visually simultaneously during the course of liquidus temperature measurement.

[0047]

Example 1-48

The optical glasses of Examples 1-48 were prepared by the usual methods according to the glass compositions indicated in Tables 1-4. That is, starting materials in the form of phosphate compounds such as phosphorus pentoxide, orthophosphoric acid, and metaphosphate were employed for P_2O_5. For the other compounds, carbonates, nitrates, hydroxides, oxides and the like were employed. These starting materials were weighed out to desired proportions and mixed into a proportioned starting material. This was then charged to a melting furnace heated to 1,000-1,200°C, melted, clarified, stirred, and homogenized, placed in a mold, and gradually cooled to obtain the optical glasses of Examples 1-48.

The compositions of the optical glasses obtained varied only slightly, by much less than 1 percent up or down, from the glass compositions shown in Tables 1 to 4. Thus, they can be said to have been nearly identical to the glass compositions shown in Tables 1-4.

As can be seen from the tables, each of the glasses of Examples 1-48 had a refractive index (nd) within the range of 1.64-1.72, an Abbé number (νd) within the range of 29-36, and a sag temperature (Ts) of not greater than 520°C. Further, none of the liquidus temperatures were greater than 900°C. No unmelted matter, loss of

transparency, residual bubbles, striae, or coloration was observed in any of the glasses of the examples.

As will be understood from these results, each of the glasses of the examples was suited to press-molding, particularly precision press-molding.

[0048]

Table 1

	Glass composition (wt%)																	Properties					
	P_2O_5	SiO_2	Al_2O_3	Na_2O	K_2O	TiO_2	Nb_2O_5	ZnO	Li_2O	B_2O_3	BaO	WO_3	Sb_2O_3	Total	Total 1	Total 2	Na_2O +K_2O	nd	vd	Tg (℃)	Ts (℃)	LT (℃)	TL
1	34.6	0.3	0.0	9.9	1.5	3.5	29.8	0.0	3.0	2.0	11.3	4.0	0.1	100.0	84.8	100.0	11.4	1.7151	30.7	470	512	890	TP
2	32.3	0.0	0.0	5.9	13.3	1.5	25.8	4.0	1.0	2.8	4.3	9.0	0.1	100.0	90.1	100.0	19.2	1.6840	32.8	455	515	780	TP
3	33.3	0.0	2.0	7.9	6.5	0.0	20.8	14.5	3.0	3.1	1.3	7.5	0.1	100.0	82.1	100.0	14.4	1.6731	35.2	413	449	780	TP
4	36.4	0.0	0.0	8.9	3.5	0.0	23.3	5.5	2.0	0.5	0.0	19.8	0.1	100.0	94.4	100.0	12.4	1.6844	33.3	460	490	870	TP
5	33.6	0.0	0.0	15.9	0.0	1.5	8.8	0.0	2.0	3.6	0.0	34.5	0.1	100.0	98.4	100.0	15.9	1.6524	35.6	445	480	850	TP
6	32.3	0.0	0.0	9.9	8.5	4.4	25.8	0.0	5.0	2.8	0.0	11.3	0.0	100.0	95.6	100.0	18.4	1.6877	30.9	410	450	880	TP
7	33.5	0.0	0.0	21.4	0.0	3.5	23.6	6.3	2.0	1.8	0.0	7.8	0.1	100.0	90.1	100.0	21.4	1.6658	32.9	420	458	820	TP
8	34.3	2.0	1.8	16.4	0.0	3.5	26.6	4.3	3.0	2.0	0.0	6.0	0.1	100.0	88.3	100.0	16.4	1.6862	31.6	470	515	800	TP
9	33.0	0.5	0.3	17.4	1.0	7.0	25.6	4.3	3.0	2.8	0.0	5.0	0.1	100.0	87.8	100.0	18.4	1.7013	29.6	465	500	780	TP
10	33.5	0.0	3.0	12.4	0.0	3.9	20.0	4.9	2.5	9.4	0.8	9.5	0.1	100.0	87.3	100.0	12.4	1.6721	32.9	460	505	800	TP
11	41.0	0.0	3.5	12.4	0.0	3.9	15.0	4.9	2.5	6.5	0.8	9.5	0.0	100.0	86.9	100.0	12.4	1.6471	34.9	450	490	780	TP
12	44.9	0.3	1.0	10.4	0.5	4.5	22.2	4.3	3.0	7.8	1.0	0.0	0.1	100.0	88.8	100.0	10.9	1.6447	34.6	480	520	860	TP
13	36.4	0.0	0.0	10.9	3.5	0.8	23.3	5.5	2.0	2.5	0.0	15.0	0.1	100.0	93.6	100.0	14.4	1.6704	34.3	450	480	830	TP

Total 1: $P_2O_5+Li_2O+Na_2O+K_2O+Nb_2O_5+B_2O_3+WO_3$

Total 2: $P_2O_5+Li_2O+Na_2O+Nb_2O_5+B_2O_3+WO_3+SiO_2+Al_2O_3+K_2O+TiO_2+ZnO+BaO+Sb_2O_3+SnO_2$

TL(Transparency loss): Loss of transparency at around pressing temperature (TP=transparent)

Table 2

	Glass Composition (wt%)																Properties					
	P2O5	Al2O3	Na2O	TiO2	Nb2O5	ZnO	Li2O	B2O3	WO3			Sb2O3	Total	Total 1	Total 2	Na2O +K2O	nd	vd	Tg (℃)	Ts (℃)	LT (℃)	TL
14	34.0	1.5	15.5	4.0	23.1	3.5	2.5	2.5	11.5	MgO 1.8		0.1	98.2	89.1	98.2	15.5	1.6880	31.3	455	500	820	TP
15	34.0	1.5	15.5	4.0	23.1	3.5	2.5	2.5	11.5	CaO 1.8		0.1	98.2	89.1	98.2	15.5	1.6882	31.3	455	500	800	TP
16	34.0	1.5	15.5	4.0	23.1	3.5	2.5	2.5	11.5	SrO 1.8		0.1	98.2	89.1	98.2	15.5	1.6882	31.3	460	505	810	TP
17	34.0	1.5	15.5	4.0	23.1	3.5	2.5	2.5	11.5	La2O3 1.8	As2O3 0.1		98.1	89.1	98.1	15.5	1.6912	31.0	460	505	850	TP
18	34.0	1.5	15.5	4.0	23.1	3.5	2.5	2.5	11.5	Y2O3 1.8		0.1	98.2	89.1	98.2	15.5	1.6911	31.0	460	505	850	TP
19	34.0	1.5	15.5	4.0	23.1	3.5	2.5	2.5	11.5	Gd2O3 1.8	SnO2 0.1		98.1	89.1	98.1	15.5	1.6910	31.0	460	505	845	TP
20	34.0	1.5	15.5	4.0	23.1	3.5	2.5	2.5	11.5	ZrO2 1.8		0.1	98.2	89.1	98.2	15.5	1.6921	30.9	465	510	880	TP
21	34.0	1.5	15.5	4.0	23.1	3.5	2.5	2.5	11.5	Ta2O5 1.8		0.1	98.2	89.1	98.2	15.5	1.6933	30.8	465	510	880	TP
22	34.0	1.5	15.5	4.0	23.1	3.5	2.5	2.5	11.5	In2O3 1.8		0.1	98.2	89.1	98.2	15.5	1.6931	30.6	455	500	840	TP
23	34.0	1.5	15.5	4.0	23.1	3.5	2.5	2.5	11.5	TeO2 1.8		0.1	98.2	89.1	98.2	15.5	1.6932	30.7	450	495	800	TP
24	34.0	1.5	15.5	4.0	23.1	3.5	2.5	2.5	11.5	Bi2O3 1.8		0.1	98.2	89.1	98.2	15.5	1.6942	30.5	450	495	820	TP

Toatal 1: P2O5+Li2O+Na2O+K2O+Nb2O5+B2O3+WO3

Total 2: P2O5+Li2O+Na2O+Nb2O5+B2O3+WO3+SiO2+Al2O3+K2O+TiO2+ZnO+BaO+Sb2O3+SnO2

TL(Transparency loss): Loss of transparency at around pressing temperature (TP=transparent)

Table 3

	Glass composition (wt%)																	Properties					
	P2O5	SiO2	Al2O3	Na2O	K2O	TiO2	Nb2O5	ZnO	Li2O	B2O3	BaO	WO3	Sb2O3	Total	Total 1	Total 2	Na2O +K2O	nd	vd	Tg (℃)	Ts (℃)	LT (℃)	TL
25	32.3	0.0	0.0	10.5	7.0	2.5	27.0	4.0	1.5	1.8	4.3	9.0	0.1	100.0	89.1	100.0	17.5	1.7051	32.0	455	500	850	TP
26	34.3	0.9	2.8	16.0	0.0	3.5	26.6	4.3	3.5	2.0	0.0	6.0	0.1	100.0	88.4	100.0	16	1.6863	31.6	460	495	780	TP
27	36.4	0.0	1.0	10.9	1.5	2.0	24.6	5.5	2.0	1.2	0.0	14.8	0.1	100.0	91.4	100.0	12.4	1.6864	33.2	475	510	860	TP
28	39.5	0.3	1.0	12.5	0.0	5.5	25.2	4.3	3.0	4.6	1.0	3.0	0.1	100.0	87.8	100.0	12.5	1.6887	31.4	470	510	840	TP
29	34.3	0.0	1.8	18.4	0.0	3.5	26.6	4.3	3.0	2.0	0.0	6.0	0.1	100.0	90.3	100.0	18.4	1.6852	31.6	440	475	840	TP
30	35.8	0.0	1.5	11.2	4.5	3.0	10.8	9.0	3.0	3.1	0.5	17.5	0.1	100.0	85.9	100.0	15.7	1.6611	35.0	410	450	850	TP
31	33.3	0.5	2.0	11.9	3.5	3.5	19.8	7.0	3.0	3.1	1.3	10.5	0.6	100.0	85.1	100.0	15.4	1.6851	34.3	430	470	850	TP
32	32.3	0.0	0.0	15.9	4.5	4.4	25.8	0.0	3.0	2.8	0.0	11.3	0.0	100.0	95.6	100.0	20.4	1.6877	30.9	420	460	780	TP
33	35.4	0.0	0.0	11.5	2.5	0.0	25.3	5.5	2.0	2.0	2.9	12.8	0.1	100.0	91.5	100.0	14	1.6814	33.8	450	480	850	TP
34	36.5	0.0	2.5	13.9	3.0	3.9	15.0	4.9	2.5	4.5	3.8	9.5	0.0	100.0	84.9	100.0	16.9	1.6771	32.9	460	500	780	TP
35	38.9	0.3	1.0	15.4	0.5	5.5	26.2	4.3	3.0	3.8	1.0	0.0	0.1	100.0	87.8	100.0	15.9	1.6807	32.0	460	500	830	TP

Total 1: P2O5+Li2O+Na2O+K2O+Nb2O5+B2O3+WO3

Total 2: P2O5+Li2O+Na2O+Nb2O5+B2O3+WO3+SiO2+Al2O3+K2O+TiO2+ZnO+BaO+Sb2O3+SnO2

TL (Transparency loss): Loss of transparency at around pressing temperature (TP=transparent)

Table 4

	Glass coposition (wt%)																	Properties					
	P_2O_5	SiO_2	Al_2O_3	Na_2O	K_2O	TiO_2	Nb_2O_5	ZnO	Li_2O	B_2O_3	BaO	WO_3	Sb_2O_3	Total	Total 1	Total 2	Na_2O $+K_2O$	nd	vd	Tg (℃)	Ts (℃)	LT (℃)	TL
36	34.7	0.0	1.5	15.8	0.0	4.1	23.5	3.6	2.5	2.5	0.0	11.7	0.1	100.0	90.7	100.0	15.8	1.6890	31.3	460	500	800	TP
37	32.5	0.0	1.5	15.8	0.0	3.9	23.9	3.6	2.5	4.7	0.0	11.5	0.1	100.0	90.9	100.0	15.8	1.6880	31.4	460	500	800	TP
38	37.8	0.0	1.5	15.0	0.0	4.1	21.2	3.0	2.8	2.5	0.0	12.0	0.1	100.0	91.3	100.0	15.0	1.6790	32.1	455	495	750	TP
39	39.0	0.0	1.5	15.8	0.0	3.7	22.1	3.6	2.0	1.0	0.0	11.2	0.1	100.0	91.1	100.0	15.8	1.6990	30.5	465	505	840	TP
40	34.7	0.0	0.8	16.8	0.0	4.1	23.5	4.8	1.0	2.5	0.0	11.7	0.1	100.0	90.2	100.0	16.8	1.6895	31.2	470	510	820	TP
41	34.7	0.0	1.5	15.8	0.0	4.1	22.0	3.6	4.0	2.5	0.0	11.7	0.1	100.0	90.7	100.0	15.8	1.6840	32.3	440	480	780	TP
42	34.7	0.0	1.5	12.5	3.3	4.5	22.7	3.6	2.5	2.5	0.0	12.1	0.1	100.0	90.3	100.0	15.8	1.6895	31.2	450	495	780	TP
43	34.7	0.0	0.0	15.8	1.5	4.1	23.5	2.6	2.5	2.5	0.0	12.7	0.1	100.0	93.2	100.0	17.3	1.6860	31.5	450	490	760	TP
44	33.2	0.0	3.0	15.8	0.0	4.8	23.5	0.0	2.5	2.5	0.0	14.6	SnO_2 0.1	99.9	92.1	100.0	15.8	1.6920	31.0	470	510	840	TP
45	34.4	0.3	1.5	15.8	0.0	0.0	25.5	3.6	2.5	2.5	5.5	8.3	0.1	100.0	89.0	100.0	15.8	1.6760	34.3	470	510	780	TP
46	37.7	0.0	2.5	15.8	1.0	4.1	15.5	4.5	3.0	3.5	2.0	10.3	0.1	100.0	86.8	100.0	16.8	1.6640	33.3	440	480	800	TP
47	38.5	0.3	2.0	15.8	2.0	4.1	24.5	4.1	2.1	2.5	0.0	4.0	0.1	100.0	89.4	100.0	17.8	1.6660	32.7	460	500	820	TP
48	34.2	0.0	2.5	15.8	1.0	4.1	19.0	4.5	3.0	3.5	2.0	10.3	0.1	100.0	86.8	100.0	16.8	1.6840	31.5	450	490	800	TP

Total 1: $P_2O_5+Li_2O+Na_2O+K_2O+Nb_2O_5+B_2O_3+WO_3$

Total 2: $P_2O_5+Li_2O+Na_2O+Nb_2O_5+B_2O_3+WO_3+SiO_2+Al_2O_3+K_2O+TiO_2+ZnO+BaO+Sb_2O_3+SnO_2$

TL (Transparency loss): Loss of transparency at around pressing temperature (TP=transparent)

[0049]

Example 49

Each of the glasses of Examples 1-48 was prepared in a quantity weighing about 1-3 L, the starting material was melted at a temperature (about 1,000-1,200°C) corresponding to a viscosity of 0.1-5 dPa·s for 2-5 hr in a SiO_2 or Pt crucible, and the glass starting material was vitrified. The crude glasses (cullets) thus obtained were reintroduced into a 2-liter Pt melt furnace capable of forming preforms. The cullets were melted at a temperature (about 1,000-1,200°C) corresponding to a viscosity of 0.1-5 dPa·s, debubbled, and clarified for 2-5 hr. After confirming during clarification that no bubbles were present in the glass, the glass was cooled to a temperature permitting molding of the glass (viscosity 5-30 dPa·s, temperature 1,000-800°C) in a melt furnace and a flow pipe (the top portion of the pipe near the melt furnace had an inner diameter of 15 mm, an inner diameter of 1.5 mm at the front end, and a total length of about 2 m). After decreasing the temperature and having achieved a prescribed viscosity, the glass was made to flow out of the flow pipe and received in a mold while being floated on an N_2 gas flow. This yielded preforms (material for precision press-molding) in the form of spheres or elliptical spheres 0.5-50 mm in diameter. The preforms obtained were uniform in both shape and weight.

[0050]

The preform was placed between upper mold 1 and lower mold 2 shown in Fig. 1, a nitrogen atmosphere was generated within quartz tube 11, and power was supplied to a heater 12 to heat the interior of quartz tube 11. The temperature within the mold was adjusted to yield a viscosity in the molded glass gob of about 10^7-10^8 dPa·s. While maintaining this temperature, push rod 13 was dropped to press upper mold 1 down from above, thereby pressing the molded glass gob within the mold. The pressure applied was 8 MPa and the pressing time was 30 sec. Following pressing, the pressure was released, the glass molded product molded by the aspherical press was gradually cooled to the glass transition temperature while still in a state of contact with upper mold 1 and lower mold 2, the glass molded

product was rapidly cooled to close to room temperature, and the glass molded by the aspherical surface was removed from the mold. The aspherical lens obtained did not lose transparency during pressing and was a lens of extremely high precision.

[0051]

Comparative Examples 1-22

The glasses described in the examples of Japanese Patent Un-examined Publication No. Hei 07-97234 (Comparative Examples 1-9), the glasses described in the examples of Japanese Patent Un-examined Publication No. 05-270853 (Comparative Examples 10-11), the glasses described in the examples of Japanese Patent Un-examined Publication No. Shō 52-132012 (Comparative Examples 12-22) were prepared and the refractive index (nd) Abbé number (vd), sag temperature (Ts), and liquidus temperature (LT) were measured. The loss of transparency property was observed. The results are given in Tables 5-7.

[0052]

Table 5

	Glass composition (wt%)														Properties					
	P2O5	Na2O	K2O	TiO2	Nb2O5	Li2O	B2O3	BaO	WO3			Total	Total 1	Total 2	Na2O +K2O	nd	vd	Tg (℃)	Ts (℃)	LT (℃)	TL
1	24.4	10	3.8	2	9.1	0	2.5	5	35.2	GeO2 8		92.0	85.0	92.0	13.8	1.70266	32.3	494	533	NON*	TP
2	17.4	10	0.8	5	7.6	0	12.5	5	33.7	GeO2 8		92.0	82.0	92.0	10.8	1.72277	26.5	479	529	850	TP
3	19.4	20	2.8	6	16.6	0	2.5	3	25.7	GeO2 4		96.0	87.0	96.0	22.8	1.72361	34.5	453	489	830	TP
4	19.4	20	2.8	6	16.6	0	2.5	3	25.7			96.0	87.0	96.0	22.8	1.74263	32.8	448	476	980	OP
5	15.4	10	12.8	6	12.6	0	5.5	3	30.7	GeO2 4		96.0	87.0	96.0	22.8	1.70035	29.13	404	444	730	TP
6	15.4	10	12.8	6	12.6	0	5.5	3	30.7			96.0	87.0	96.0	22.8	1.7231	27.8	400	435	950	OP
7	18.4	17	2.8	6	12.6	0	2.5	3	30.7	GeO2 4	Cs2O 3	93.0	84.0	93.0	19.8	1.70815	31.3	411	448	800	TP
8	18.4	17	2.8	6	12.6	0	2.5	3	30.7		Cs2O 3	93.0	84.0	93.0	19.8	1.7275	29.8	405	444	970	OP
9	23.4	13.5	2.8	6	12.6	0.5	3	8.7	19.5	GeO2 10		90.0	75.3	90.0	16.3	1.69121	30.5		565	930	TP

Total 1: P2O5+Li2O+Na2O+K2O+Nb2O5+B2O3+WO3

Total 2: P2O5+Li2O+Na2O+Nb2O5+B2O3+WO3+SiO2+Al2O3+K2O+TiO2+ZnO+BaO+Sb2O3+SnO2

TL (Transparency loss): Loss of transparency at around pressing temperature (TP=transparent, OP=opaque)

* Liquidus temperature was not recognized

Table 6

	Glass composition (wt%)																	Properties				
	P2O5	SiO2	Al2O3	Na2O	K2O	TiO2	Nb2O5	Li2O	B2O3	WO3			Sb2O3	Total	Total 1	Total 2	Na2O +K2O	nd	vd	Ts (℃)	LT (℃)	TL
10	20	1	3	5	25	10	20	0.8	10	5		As2O3 0.2	0	99.8	85.8	99.8	30	1.65077	33.1	525	995	TP
11	30	4	0	5	20	5	30	0	2	0	CaO 3.9		0.1	96.1	87.0	96.1	25	1.68704	29.1	550	975	OP

Total 1: P2O5+Li2O+Na2O+K2O+Nb2O5+B2O3+WO3

Total 2: P2O5+Li2O+Na2O+Nb2O5+B2O3+WO3+SiO2+Al2O3+K2O+TiO2+ZnO+BaO+Sb2O3+SnO2

TL (Transparency loss): Loss of transparency at around pressing temperature (TP=transparent, OP=opaque)

Table 7

	Glass composition (wt%)																Properties				
	P2O5	Na2O	K2O	TiO2	Nb2O5	ZnO	Li2O	B2O3			Sb2O3		Total	Total 1	Total 2	Na2O +K2O	nd	vd	Ts (℃)	LT (℃)	TL
12	44.37	0	0	0	31.15	0	0	24.48					100.00	100.00	100.00	0	1.6549	36.6	550	940	OP
13	28.09	1.37	11.8	0	43.69	0	1.14	13.87					100.00	100.00	100.00	13.21	1.7178	28.4	550	950	OP
14	28.57	0	10.6	0	44.43	0	2.27	14.1					100.00	100.00	100.00	10.63	1.727	27.7	540	970	OP
15	27.62	2.73	13.1	0	42.96	0	0	13.64					100.00	100.00	100.00	15.78	1.7086	29	550	960	OP
16	27.24	0	17	0	42.36	0	0	13.44					100.00	100.00	100.00	16.96	1.6988	29.1	540	990	OP
17	30.04	0	9	0	23.73	2.38	0	8.07	MgO1 .99	CaO 2.78	SrO 6.55	PbO 14.5 1	73.22	70.84	73.22	9	1.7178	36.9	570	960	OP
18	33.64	0	11.4	0	23.95	4.4	0	10.45	MgO 3.63	CaO 5.06	SrO 7.47		83.85	79.45	83.85	11.41	1.6538	38.7	560	950	OP
19	34.2	0	6.84	0	34.62	0	0	10.32	MgO 6.7	CaO 7.32			85.98	85.98	85.98	6.84	1.7009	32.5	580	980	OP
20	35	0	7	0	33.03	0	0	9.3	MgO 7.41	CaO 8.26			84.33	84.33	84.33	7	1.6946	33.6	580	960	OP
21	29.76	0	13.2	0	41.15	0	0	8.98	MgO 2.81	CaO 4.06			93.13	93.13	93.13	13.24	1.7174	29.5	560	970	OP
22	26.8	0	13	1.47	23.84	0	0	2.87	GeO2 18.83	PbO 13.16			68.02	66.55	68.02.	13.04	1.7262	34.2	530	860	OP

Total 1: P2O5+Li2O+Na2O+K2O+Nb2O5+B2O3+WO3
Total 2: P2O5+Li2O+Na2O+Nb2O5+B2O3+WO3+SiO2+Al2O3+K2O+TiO2+ZnO+BaO+Sb2O3+SnO2
TL (Transparency loss): Loss of transparency at around pressing temperature (OP=opaque)

[0053]

The glasses described in the examples of Japanese Patent Un-examined Publication No. Hei 07-97234 (Comparative Examples 1-9)(Table 5) had refractive indexes of not more than 1.73, often resulting in characteristics whereby the sag temperature Ts exceeded 520°C. This was attributed to an Li_2O content of 0-0.5 weight percent. Although there were some examples (Comparative Examples 3, 5, 7) which had a Ts of less than 520°C despite an Li_2O content falling within the range of 0-0.5 weight percent, those examples were problematic in that expensive GeO_2 was employed as a glass starting material. When the GeO_2 was removed from the glasses of these examples (Comparative Examples 4, 6, 8), there was a problem in that the liquidus temperature (LT) exceeded 900°C.

[0054]

The glasses described in the examples of Japanese Patent Un-examined Publication No. 05-270853 (Comparative Examples 10-11) (Table 6) had refractive indexes of 1.64-1.73. All of them had liquidus temperatures exceeding 900°C. The Ts of these glasses also exceeded 520°C.

[0055]

The glasses described in the examples of Japanese Patent Un-examined Publication No. Shō 52-132012 (Comparative Examples 12-22) (Table 7) had refractive indexes of 1.64-1.73 and a Ts exceeding 520°C. Further, excluding the glasses described in Examples 2 and 3 (Comparative Examples 13 and 14), the fact that Li_2O was not incorporated was thought to be one cause of the Ts exceeding 520°. Even in the glasses of Examples 2 and 3 (Comparative Examples 13 and 14) where Li_2O was incorporated in a quantity exceeding 0.5 weight percent, the Ts exceeded 520°C and the liquidus temperature exceeded 900°C.

[0056]

As set forth above, according to the present invention, it is possible to obtain optical glass having both a low refractive index and liquidus temperature while not exhibiting crystallization, bubble retention, striae, coloration, or improper deformation. Accordingly, the use of this glass permits precision press-molding at

relatively low temperature and prevents fusion of the glass with the mold during pressing. Further, since a high thermal load is not exerted on the press machine, there is no risk of product damage due to heat.

[0057]

The optical glass of the present invention has good resistance to loss of transparency due to having a liquidus temperature of not greater than 900°C and affords good press-molding characteristics with heating in the relatively low temperature range due to having a sag temperature of not greater than 520°C. Thus, the molding temperature can be 540°C or less. Further, the stability of the glass during press-molding is good.

[0058]

Due to the low liquidus temperature, resistance to loss of transparency is good and glass crystallization is prevented both during the molding of molten glass into material for use in precision press-molding and during heating as part of press-molding. Still further, it is possible to obtain high-quality optical glass in which bubbles generated during glass melting do not remain in the glass and which does not exhibit striae, coloration, or improper deformation.

The present disclosure relates to the subject matter contained in Japanese Patent Application No. 2001-19854 filed on January 29, 2001, which is expressly incorporated herein by reference in its entirety.